JERICO-S3 DELIVERABLE

Joint European Research Infrastructure for Coastal Observatories

Science, Services, Sustainability

DELIVERABLE #, WP# and full title	JERICO-S3 D7.9 - WP7 - "Technological innovation demonstration report"
5 Key words	Technology, Innovation, Observation, Coastal, Oceanography
Lead beneficiary	PLOCAN
Lead Author	Andrés Cianca and Eric Delory (PLOCAN)
Co-authors	Jérome Blandin, Dominique Durand, Andrew Luke King, Antoine Gremare, Enoc Martínez, Simon Jirka, Emilie Poisson Caillault, Michel Repecaud, Alain Lefebvre, Joaquin del Rio, Tanguy Bescond, Bertrand Moreau, Simone Marini, Laurent Delauney
Contributors	See report tables for a full list of contributors to each technology
Final version date/ Submission date (dd.mm.yyyy)	15.07.2024

Nature: R

(R = Report, P = Prototype, D = Demonstrator, O = Other)

Dissemination level : PU

PU = Public, PP = Restricted to other programme participants (including the Commission Services), RE = Restricted to a group specified by the consortium (including the Commission Services), CO = Confidential, only for members of the consortium (including the Commission Services)

GRANT N°: 871153
PROJECT ACRONYME : JERICO-S3
PROJECT NAME : Joint European Research Infrastructure for Coastal Observatories - Science, services, sustainability
COORDINATOR : Laurent DELAUNEY - Ifremer, France - jerico@ifremer.fr

According to the Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation) and the 78-17 modified law of 6 January 1978, you have a right of access, rectification, erasure of your personal data and a right of restriction to the data processing. You can exercise your rights before the Ifremer data protection officer by mail at the following address: IFREMER – Délégué à la protection des données- Centre Bretagne – ZI de la Pointe du Diable – CS 10070 – 29280 Plouzané - FRANCE or by email: dpo@ifremer.fr + jerico-s3@ifremer.fr
Ifremer shall not hold your personal data for longer than necessary with regard to the purpose of the data processing and shall destroy it thereafter.

DOCUMENT TECHNICAL DESCRIPTION

Document ID	JERICO-S3-WP7-D7.9-15.07.2024-V1.0

REVISION HISTORY

Revision	Date	Modification	Author
V1.0	15/07/2024	Initial draft	Andrés Cianca, Eric Delory

APPROVALS

	Name	Organisation	Date	Visa
Coordinator	Laurent Delauney	Ifremer	15/07/2024	X
WP Leader	Eric Delory	PLOCAN	15/07/2024	X

Diffusion list

Consortium beneficiaries	Third parties	Associated Partners	other
X	X		

PROPRIETARY RIGHTS STATEMENT

THIS DOCUMENT CONTAINS INFORMATION, WHICH IS PROPRIETARY TO THE **JERICO-S3** CONSORTIUM. NEITHER THIS DOCUMENT NOR THE INFORMATION CONTAINED HEREIN SHALL BE USED, DUPLICATED OR COMMUNICATED EXCEPT WITH THE PRIOR WRITTEN CONSENT OF THE **JERICO-S3** COORDINATOR.

TABLE OF CONTENT

EXECUTIVE SUMMARY **4**
DEMONSTRATION MISSION REPORTS **5**
Autonomous Coastal Observation Benthic Station (ACOBS) 5
Water-Sample filtration and Preservation Device (WASP) 9
Plankton dynamics Sensor Package (PSP) 15
CONCLUSION **20**

EXECUTIVE SUMMARY

The technological innovation demonstration activities within the JERICO-S3 project's WP7 work package have showcased significant advances for ocean observation. Three observing system solutions have been demonstrated that combine the physics, chemistry and biology compartments: The Autonomous Coastal Observing Benthic Station (ACOBS), the Water-Sample Filtering and Preservation Device (WASP) and the Plankton dynamics Sensor Package (PSP).

ACOBS integrates data from various sources simultaneously, such as bottom seawater characteristics, diffusive and total oxygen fluxes at the sediment-water interface, benthic activity at the sediment-water interface and in the upper sediment column. ACOBS enhances our understanding of coastal processes, sediment-water interactions, and benthic ecosystems.

WASP enables automated collection of bulk seawater samples for nutrient analysis and automated filtration of phytoplankton samples for environmental DNA (eDNA) and metabarcoding. The sample collection is complemented by real-time observation of essential ocean variables, including hydrographic characteristics, chlorophyll-a fluorescence, coloured dissolved organic matter fluorescence, and turbidity. WASP contributes to both scientific research and environmental monitoring by providing valuable data on water quality and phytoplankton communities.

PSP is built around the COSTOF2 technological core, also used to develop the EGIM (EMSO Generic Instrument Module) and enhances it with new biologically related sensors, including zooplankton and nitrate sensors, and a processing unit that dynamically adjusts the sampling strategy based on real-time observations. The PSP also aims to provide standardised, real-time data flow for plankton dynamics, contributing to a better understanding of marine ecosystems.

These three developments collectively advance integrated ocean observation by addressing scientific and technological needs. They represent crucial steps toward a more comprehensive understanding of our oceans and their ecosystems. The deliverable content consists in tables summarising the demonstration mission objectives and outcomes. As reminded in each table, since a Steering Committee decision of the 23-25 April 2024, Brussels, the details of this deliverable have been moved to D7.7 for confidentiality reasons and to allow for using the content in journal publications.

DEMONSTRATION MISSION REPORTS

Autonomous Coastal Observation Benthic Station (ACOBS)

Instrument / platform short name: **ACOBS** Instrument / platform long name: **Autonomous Coastal Observation Benthic Station**	Instrument / platform owner institute and operator: **EPOC (UMR 5805)** **OASU (UAR 2567 POREA)**
Mission leading entity/ies: **CNRS UB**	Involved partners: **CNRS UB**

Mission motivation

The motivation for the development of ACOBS was threefold:
(1) the necessity to achieve operational observations of benthic processes due to their major importance in the functioning of coastal marine ecosystems and the provision of ecosystem services
(2) the lack of maturity of biological and biogeochemical operational observations, and more specifically those focusing on the sediment-water interface, and
(3) the major interest in pursuing and integrating previous JERICO technological developments on benthic biological activity and O_2 flux assessments at the sediment-water interface.

Instrument /platform description

ACOBS is composed of two main devices, namely: a main frame, and a sediment profile imager that can be either jointly (in most cases) or independently deployed. ACOBS main frame can be fitted with (1) a multiparameter probe (environmental parameters, (2) a sediment O_2 microprofiler (O_2 diffusive flux), (3) a new autonomous benthic chamber (see below) and/or an eddy covariance system and/or a BOGOSS system (O_2 total flux). The sediment profile imager is allowing for time series acquisition of both sedimentological (sediment reworking) and biological (biological activity) processes.

Innovations developed in Jerico-S3

The main innovations developed within ACOBS are dealing with (1) new technological developments, and (2) the integration of those new developments with previous ones, including some of those achieved within previous JERICO projects.
New developments include: (1) the design and construction of a new autonomous benthic chamber for repeated total O_2 flux measurements, and (2) software refinements for the analysis of sediment profile image time series.
Integration in ACOBS is aiming at the simultaneous acquisition of environmental, sedimentological, biogeochemical, and biological time series.

Map of observation effort / Place of demonstration

There were several series of preliminary deployments/tests of ACOBS new technological developments, which took place either in laboratory mesocosms (new autonomous benthic chamber) or in the Arcachon Lagoon (processing of the time series generated by the sediment Image profiler) (see D7.7 for details). Field demonstration surveys of the "full" ACOBS configuration then took place at a shallow station (7m depth) in the Arcachon Lagoon (**Figure 1**).

Figure 1*: Map showing the location of the deployment station (44°41.230 N, 1°05.743W) within the Arcachon Lagoon (Bay of Biscay)*

Mission report summary

The ACOBS field demonstration survey consisted in two distinct deployments, which both took place during May 2024.

A first deployment was specifically dedicated to test the ability of ACOBS to perform simultaneous repeated measurements of diffusive (using the sediment O_2 microprofiler) and total (using the new autonomous benthic chamber) O_2 fluxes. It was achieved on May 18 and lasted for 2h35 allowing for two repeated flux measurements. Results (**Figure 2**) validated the efficient functioning of these two components of ACOBS and showed: (1) the relative constancy of total O_2 fluxes over this temporal time scales, (2) the major impact of bioturbation on the shape of O_2 sediment profile and derived diffusive fluxes, and (3) the strong difference between total and diffusive O_2fluxes thereby suggesting the major importance of biological processes in controlling the intensity of organic remineralisation at the sediment-water interface.

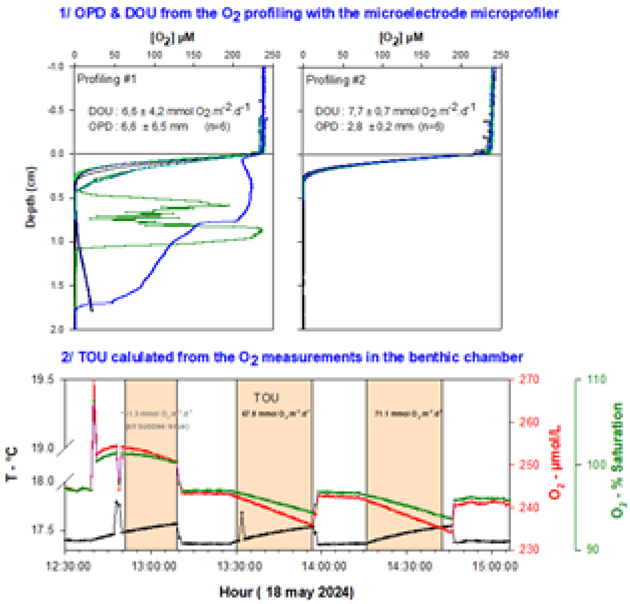

***Figure 2**: Main results from the May 18 deployment. Vertical O_2 profiles within the upper sediment column during the two measuring sequences (upper panes). Temporal changes in temperature and O_2 concentration within the new autonomous chamber (lower pane). Derived and total O_2 fluxes are also shown on higher and lower panes, respectively.*

The second deployment took place between May 22 and 24. It was designed to test ACOBS in a "full" configuration. At this occasion, ACOBS main frame, included: (1) a multiparameter probe (T, S, O_2 and turbidity, (2), a sediment O_2 microprofiler (diffusive O_2 flux) and the new autonomous chamber (total O_2 flux). The sediment image profiler (biological activity and sediment reworking) was independently deployed with a frequency image acquisition of $1*5min^{-1}$. ACOBS proved efficient in collecting high-frequency time series of environmental parameters (**Figure 3A-B**). Temporal changes in salinity and turbidity were clearly cued by tides, which was not the case for both temperature and O_2 concentrations. ACOBS proved also efficient in collected continuous time series of O_2 concentrations within the new autonomous chamber (**Figure 3C**). However, it was not always possible to derive total O_2 fluxes from those changes (**Figure 3D**). This was especially the case during major erosion periods (**Figure 3E**), which probably degraded the watertightness of the chamber. In this sense, the deployment station certainly proved not optimal for deployments of this duration. The analysis of sediment profile image time series also showed major peaks in benthic biological activity (**Figure 3F**) mostly due to the presence of high crab density. These peaks appear to a certain extent correlated with sediment erosion suggesting that this process could be cued by biological activity and only indirectly correlated with (high) tides (**Figure 3G**).

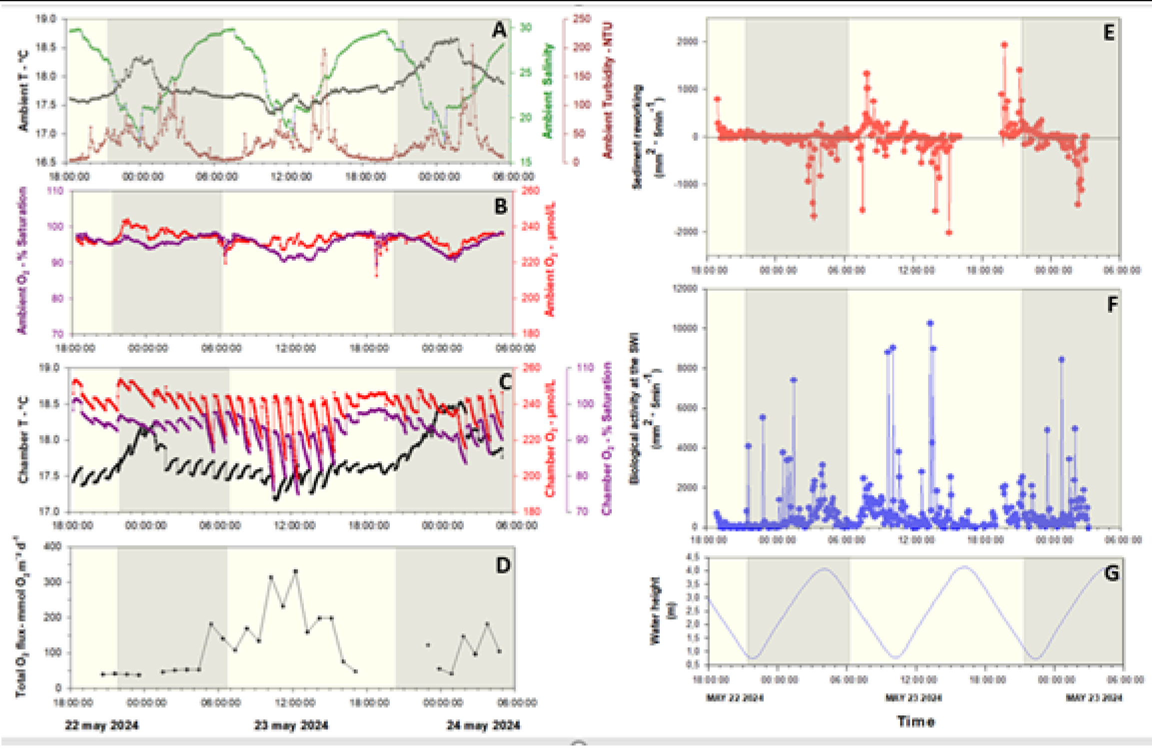

***Figure 3**: Main results from the May 22-24 deployment. Examples of collected: A-B: Environmental time series. C-D: Biogeochemiical time series. E: Sedimentological time series, F: Biological time series, G: Tidal time series.*

Overall, these two deployments proved the ability of ACOBS to acquire simultaneous "high-frequency" time series of environmental, biogeochemical, biological and sedimentological parameters/processes. Besides some technological adjustments, our main perspective now consists in deploying ACOBS in deeper and "less dynamic" environments to better assess the optimal frequency acquisition of total O_2 fluxes and to better identify their controlling factors through cross-correlation approaches including a range of integration durations of potential controlling factors.

Detailed information has been reported in Jerico-S3 Deliverable D7.7. This information is confidential at the time of writing this report because its content is being used in the writing of a journal paper. You can contact the lead contributor for more information.

Contributors list:

Bruno Deflandre (UMR EPOC, Université de Bordeaux, CNRS, UMR 5805, Bâtiments B18N, Allée Geoffroy Saint-Hilaire, 33615 Pessac, France), **Franck Delalée** (OASU, UAR 2567 POREA, Bâtiment B18N, Allée Geoffroy Saint Hilaire, CS50023, 33615 Pessac, France), **Sylvia Lopez** (OASU, UAR 2567 POREA, Bâtiment B18N, Allée Geoffroy Saint Hilaire, CS50023, 33615 Pessac, France), **Yannick Geerebaert** (UMR EPOC, Université de Bordeaux, CNRS, UMR 5805, Station Marine d'Arcachon, 2 rue du Professeur Jolyet, 33120 Arcachon, France), **Alicia Romero-Ramirez** (UMR EPOC, Université de Bordeaux, CNRS, UMR 5805, Station Marine d'Arcachon, 2 rue du Professeur Jolyet, 33120 Arcachon, France), **Antoine Grémare** (UMR EPOC, Université de Bordeaux, CNRS, UMR

5805, Station Marine d'Arcachon, 2 rue du Professeur Jolyet, 33120 Arcachon, France) - lead

Water-Sample filtration and Preservation Device (WASP)	
Instrument / platform short name: **WASP** Instrument / platform long name: **Water-Sample filtration and Preservation Device**	Instrument / platform owner institute and operator: NIVA
Mission leading entity/ies: NIVA	Involved partners: NIVA
Mission motivation	
The WASP was demonstrated on two missions on the MS Color Fantasy FerryBox in the Skagerrak/Kattegat region of the Eastern North Sea Integrated Regional Site (KASKEN IRS). The WASP missions were carried out to validate automated sampling of bulk seawater for nutrient concentrations (water sampling part of the WASP) and automated filtration of suspended material for environmental DNA (eDNA) metabarcoding (sample filtration and preservation part of the WASP). The first mission took place in December 2023 and the second mission took place in April 2024. The first mission was also an integration test of WASP with the FerryBox system, especially the filtration component of the WASP that had not yet been tested in a FerryBox observing platform setting. The missions were also designed to characterise seasonal variability between winter and spring seasons as well as spatial variability where multiple samples were collected along a transect with gradients in salinity, temperature, and water mass origin.	
Instrument /platform description	
The WASP is a combination of an ISCO Teledyne refrigerated autosampler, a modified Mclane PPS sample filtration system, and a FerryBox system with sensors of essential ocean variables and metadata (salinity, temperature, chlorophyll a [chl a], latitude, longitude, time, etc.) (Fig. 1). The WASP can collect bulk seawater for shore-based analysis of macronutrients phosphate, nitrate, and silicate (or other dissolved analytes) and also filter samples onto membrane filters for phytoplankton and metazoan environmental DNA for shore-based analysis of species composition (or other suspended or particulate material). D7.4 reports a series of benchmarking tests carried out including filter types that can be used, water filtration efficiency, total volume filtered, collection of different phytoplankton functional groups, preservation techniques, and quality of DNA extracted. D7.7 reports a full description of the WASP as well as integration of the	

samplers with the FerryBox system on board MS Color Fantasy and first validation tests carried out.

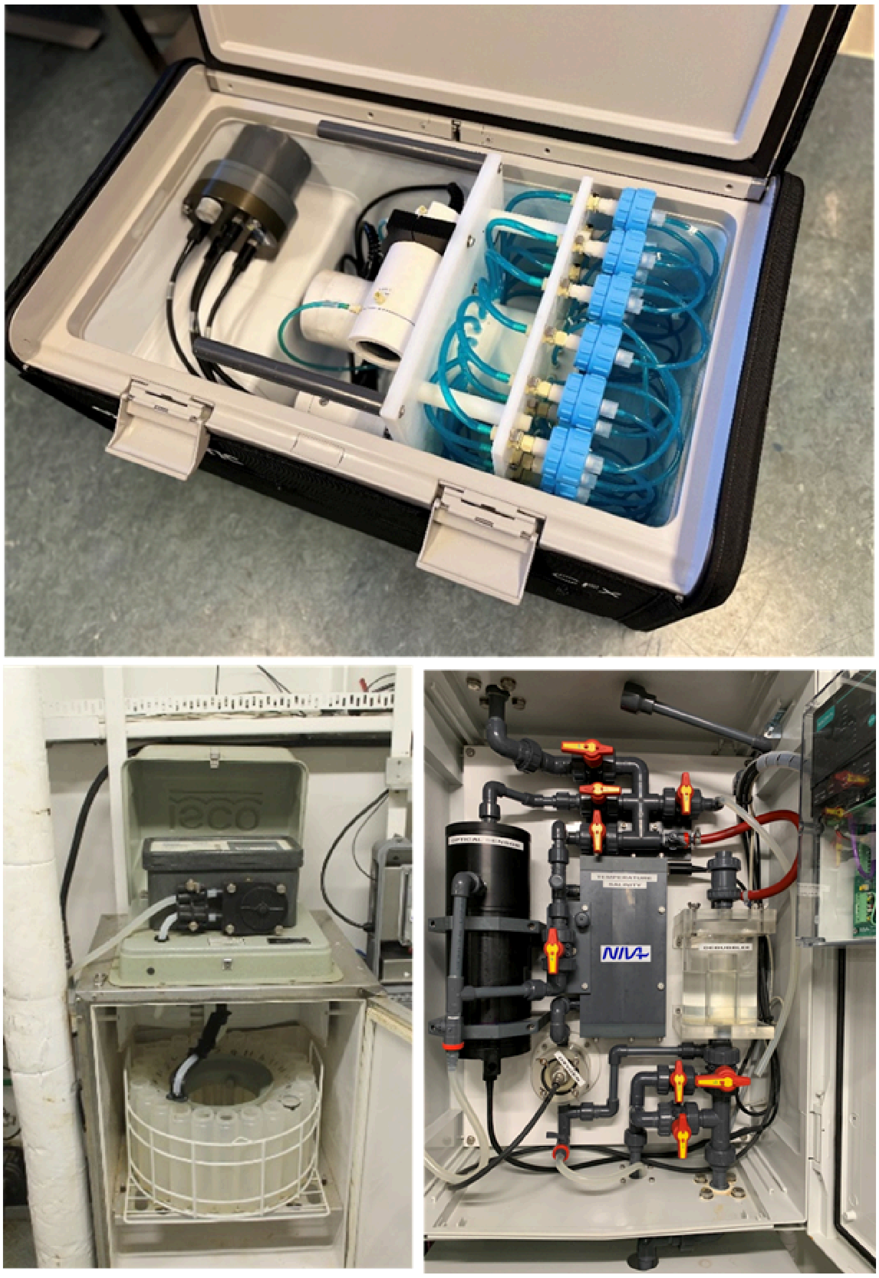

Figure 1: *WASP sampling system. Top: modified Mclane PPS for particulate matter sampling; Bottom left: ISCO Teledyne refrigerated autosampler for water samples; Bottom right: FerryBox sensors including SeaBird SBE45 for salinity-temperature and Turner Designs C3 for chlorophyll a, cDOM, and turbidity. Figure is from D7.4.*

Innovations developed in Jerico-S3
The WASP is an instrument that can autonomously collect/filter seawater samples and preserve the samples (cooling, freezing, preservative reagent addition, etc.) on an observing platform. In the frame of these demonstrations, a FerryBox observing platform was used in which GPS fences were implemented to trigger sample collection. At present, the observing community lacks sensors that can measure certain biological and biogeochemical EOVs (e.g., contaminants, nutrients, particulate C and N, pigment- or DNA-based biodiversity metrics). Some new sensor technologies are under development, but these are not yet reliable enough for high precision/accuracy measurements. The WASP enables observing platforms to autonomously and automatically collect samples for these EOVs for later retrieval and analysis in a shore-based lab. The WASP is also an innovation for state-of-the-art sensors that measure EOVs (e.g., phytoplankton chl a, coloured dissolved organic matter, etc.) since these sensors still require occasional sampling for validation of sensor values. The WASP can collect seawater samples for analysis in shore-based labs to support/validate sensor data. While the WASP was used in the demonstrations to collect bulk seawater for nutrients and sample filtration eDNA, a variety of other EOVs could be collected in future deployments of the WASP as mentioned above. Additionally, the preservation techniques used for bulk seawater and eDNA samples were cooling at 5 °C and rinse/soak in ethanol, respectively. However, a variety of other preservation techniques are also possible to implement with the WASP. Any liquid preservative reagent can be used for bulk seawater or filtered samples – as long as there is chemical compatibility with the tubing and filtration/sampling manifolds. And a freezing option is also possible for the filtered samples when the sample filtration part of the WASP is placed in a programmable cooler that can adjust temperature from ~-20 °C to 5+ °C. Preloading the sampling tubes and filter holders with ~50% ethanol would prevent sampling lines from freezing at -20 °C and allow seawater samples to displace the ethanol, eventually be pumped to dryness, and then frozen.
Map of observation effort / Place of demonstration
The demonstrations were carried out in the KASKEN IRS region between Oslo, Norway and Kiel, Germany on board the MS Color Fantasy that hosts a NIVA FerryBox system (Fig. 2). Two demonstrations were carried out during the project – 5-6 December 2023 and 19-21 April 2024. A total of 20 nutrient and 35 eDNA samples were collected using the WASP during the two demonstrations: 16 samples were collected during the December 2023 demonstration and a total of 19 samples were collected during the April 2024 demonstration. The December 2023 demonstration collected samples in the Oslo fjord and Skagerrak region (samples 1-10) as well as in the southern Kattegat region just north of Kiel, Germany (samples 11-16). The April 2024 demonstration collected samples primarily from the Oslo fjord and Skagerrak region (samples 17-35).

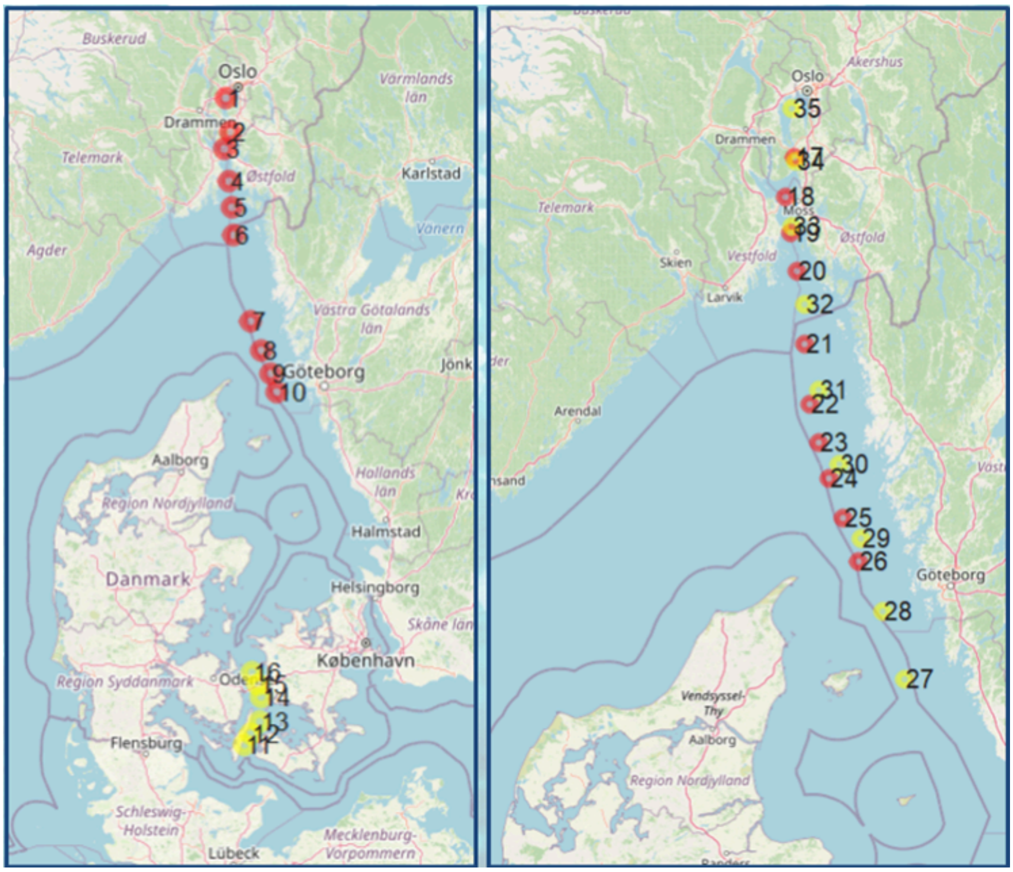

***Figure 2**: Locations of WASP sample collection during the December 2023 demonstration (left panel; samples 1-16) and the April 2024 demonstration (right panel: samples 17-35). For each cruise, the "red" and "yellow" samples were collected on different dates, see Table 1.*

Mission report summary

Nutrients and FerryBox sensor data: Nutrient samples were taken directly from the ISCO refrigerated autosampler, kept cool at 5 °C, and conserved with 4M H_2SO_4 before analysis analysis at NIVA's analytical facility using a conventional nutrient autoanalyzer for nitrate+nitrite, ammonium, phosphate, silicic acid, total nitrogen, and total phosphorus. Nutrient data as well as location, temperature, salinity, and chl a are reported in Table 1. Both demonstration periods exhibited a decrease in concentration of inorganic nutrients along the transect from within the eutrophicated Oslo fjord and towards Skagerrak.

eDNA: Filters for eDNA were returned to the lab for processing and analysis. DNA was isolated from filters using PowerSoil commercial kits and metabarcoding was carried out with Illumina MiSeq v3. Additional methodological details can be found in D7.7. eDNA metabarcoding results are shown in Fig. 3. In general, there was a relatively high proportion of animal sequences (20-50%), as the water was not pre-filtered to remove zooplankton. In December 2023, there was a correlation between the proportion of centric diatom reads and chl a fluorescence. In April, the proportion of diatom reads was generally low, which is consistent with the low chl a fluorescence (< 2.5 μg/L^{-1}), suggesting a post-bloom situation. Furthermore, the metabarcoding data showed a change in community composition between the freshwater-influenced Oslo fjord compared to the Atlantic water flowing into Skagerrak (the current boundary, as indicated by change in salinity, was between sample 20 and 21, cf. Table 1 and Fig. 2). There was a slightly lower proportion of dinoflagellates+ciliates (microzooplankton) than metazoa (zooplankton) in the freshwater-influenced Oslo fjord compared to the Atlantic water flowing into Skagerrak in April. The preliminary results show that metabarcoding of eDNA sampled with the WASP adequately sampled spatial and seasonal differences in taxonomic composition, similar to benchtop filtration.

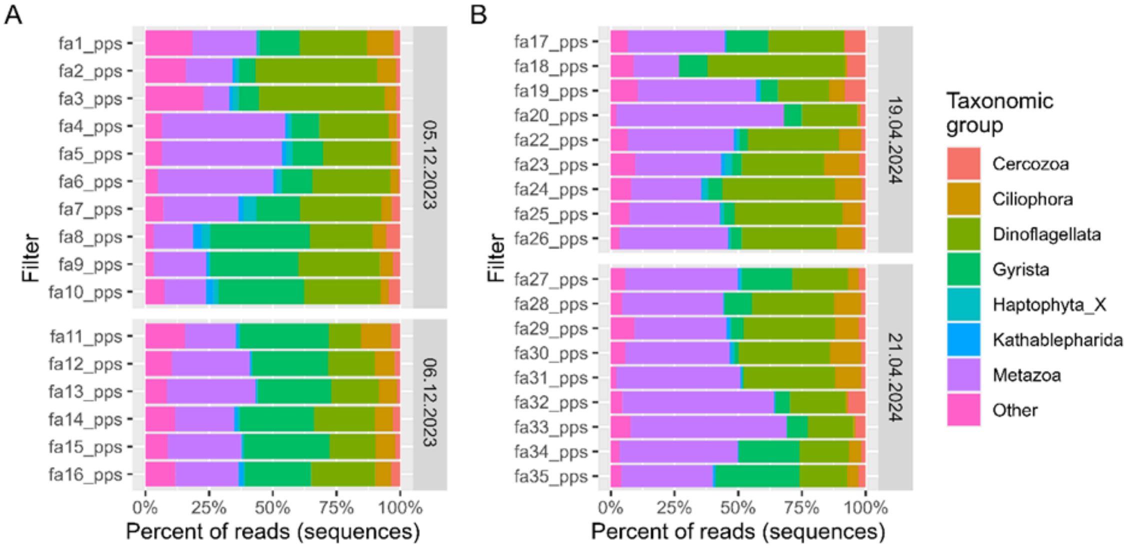

***Figure 3**: Change in community composition along the transects, as assessed by percent of reads (sequences) from metabarcoding of eDNA sampled with the WASP. A: 5th and 6th December 2023, B: 19th and 22nd April 2024. Samples fa1-10 are from a north-to-south transect in Oslo fjord and Skagerrak. Samples fa11-15 are from a south-to-north transect near Kiel, Germany. Samples fa17-26 are from a north-to-south transect in Oslo fjord and Skagerrak. And samples fa27-35 are from a south-to-north transect in Oslo fjord and Skagerrak. The taxonomic group "Gyrista" includes diatoms. Station locations are denoted in Figure 2.*

Table 1: Sensor data (chl a fluorescence[µg/L], salinity [PSU], temperature [°C]) and concentrations of dissolved inorganic nutrients and total N and P (µM) from the demonstration transects in December 2023 and April 2024.

Sample	Date	Lat.	Lon.	Temp. °C	Sal. PSU	Chl. a	NH4	PO4	NO2+NO3	SiO2	Tot-N	Tot-P
FA1	05.12.2023	59.8301	10.5737	5	30	0.75	0.29	0.34	4.26	20.14	20.7	1.26
FA2	05.12.2023	59.5845	10.6302	7.3	31.1	0	0.29	0.25	3.24	14.31	17.13	0.97
FA3	05.12.2023	59.4644	10.5555	8.9	31.2	0	0.29	0.2	2.33	10.15	13.56	0.81
FA4	05.12.2023	59.2283	10.6156	5.2	29.9	0	0.29	0.15	1.83	9.32	12.14	0.65
FA5	05.12.2023	59.0390	10.6676	4.5	28.6	0	0.47	0.14	1.7	9.32	12.85	0.65
FA6	05.12.2023	58.8339	10.6816	4.9	29.3	0.24	0.59	0.14	1.04	5.49	11.42	0.68
FA7	05.12.2023	58.1915	10.9268	4.6	28.6	0.94	0.76	0.15	0.74	4.66	11.42	0.74
FA8	05.12.2023	57.9676	11.0826	3.3	25.2	1.26	0.59	0.13	0.56	4.33	12.14	0.71
FA9	05.12.2023	57.8016	11.1963	3.5	22.7	1.57	0.47	0.11	0.33	3.99	11.42	0.65
FA10	05.12.2023	57.6547	11.2909	3.6	21.6	1.37	0.47	0.11	0.3	4.49	12.14	0.58
FA11	06.12.2023	54.8681	10.8368	5.3	11.3	4						
FA12	06.12.2023	54.9577	10.9270	5.5	12	3.86						
FA13	06.12.2023	55.0500	11.0421	6	13.4	3.66						
FA14	06.12.2023	55.2500	11.0800	5.6	12.8	3.44						
FA15	06.12.2023	55.3500	11.0400	5.8	12.9	3.3						
FA16	06.12.2023	55.4500	10.9400	5.5	14.3	2.55						
FA17	19.04.2024	59.6210	10.6246	7	21.9	1.22	0.65	0.06	2.33	17.64	19.99	0.58
FA18	19.04.2024	59.4489	10.5480	6.4	17.6	0.53	0.76	0.07	3.15	24.97	22.85	0.48
FA19	19.04.2024	59.2957	10.5922	6.4	19.9	2.11	0.53	0.05	2.39	18.97	19.28	0.48
FA20	19.04.2024	59.1277	10.6456	6.5	19.4	2.46	0.53	0.04	1.94	15.48	17.85	0.42
FA21	19.04.2024	58.8008	10.7167	7.6	25.9	1.48	0.65	0.04	1.3	5.66	15.71	0.55
FA22	19.04.2024	58.5355	10.7582	7.8	27.2	0.77	0.53	0.03	1.13	3.66	14.28	0.42
FA23	19.04.2024	58.3599	10.8316	7.9	28.2	0.68	0.59	0.03	1.63	3.16	15.71	0.42
FA24	19.04.2024	58.1989	10.9230	7.7	27.8	0.9	0.53	0.03	1.19	3.66	14.28	0.39
FA25	19.04.2024	58.0180	11.0438	7.9	26.4	2.06	0.59	0.03	1.87	3.66	17.85	0.42
FA26	19.04.2024	57.8224	11.1776	7.7	26.7	1.6	0.65	0.03	0.96	3.5	12.14	0.48
FA27	21.04.2024	57.2763	11.5721	7.9	17.7	1.84						
FA28	21.04.2024	57.5953	11.3789	7.6	21.7	1.92						
FA29	21.04.2024	57.9277	11.1899	7.5	24.1	1.61						
FA30	21.04.2024	58.2635	11.0029	7.6	26.4	1.46						
FA31	21.04.2024	58.5983	10.8379	7.7	26.6	1.32						
FA32	21.04.2024	58.9811	10.7066	6.5	19.2	1.93						
FA33	21.04.2024	59.3223	10.6063	5.8	22.9	0.35						
FA34	21.04.2024	59.6080	10.6337	6.9	22.2	1.38						
FA35	21.04.2024	59.8361	10.5999	5.9	20.9	1.64						

Detailed information has been reported in JERICO-S3 Deliverable D7.7. This information is confidential at the time of writing this report because its content is being used in the writing of a journal paper. You can contact the lead contributor for more information.

Contributors list:
Anette Engesmo (NIVA), Øyvind Tangen Ødegaard (NIVA), Elianne Egge (NIVA), Pierre Jaccard (NIVA, Sonja Kistenich (NIVA), Ann Kathrin Baur (NIVA), Siri Moy (NIVA), Andrew King (NIVA) - Lead

Plankton dynamics Sensor Package (PSP)	
Instrument / platform short name: **PSP** Instrument / platform long name: **Plankton dynamics Sensor Package**	Instrument / platform owner institute and operator: **IFREMER**
Mission leading entity/ies: **IFREMER**	Involved partners: **IFREMER, CNRS, UPC and 52 North**
Mission motivation	
The implementation of autonomous AI-driven platforms for in situ coastal observatories represents a groundbreaking scientific endeavour. These platforms aim to help deepen our understanding of phytoplankton dynamics in highly eutrophicated ecosystems, among other scientific challenges. Eutrophication leads to massive phytoplankton blooms and these blooms have far-reaching consequences, including Harmful Algal Blooms (HABs). Understanding their causes and effects is crucial for managing coastal ecosystems. Coastal observatories address complex processes. The observational modules required should involve physics, chemistry, and biology, providing a holistic view of ecosystem dynamics. The challenge in the JERICO community was to build a platform/module that satisfies the following criteria: **Technological Innovation**: The module should leverage AI and autonomous capabilities, to operate in-situ, collecting data from sensors. This technological innovation enhances the ability to monitor and analyse coastal environments in an adaptive fashion and with broader scientific coverage. **Balancing Commonality and Adaptability**: While a common sensor set ensures consistency, regional adaptability is essential. Coastal conditions vary, and observatories must respond to specific ecosystems.	

Pan-European Interest: Research transcends national boundaries, fostering Pan-European collaboration. The system should build upon previous EU projects, leveraging existing achievements. **Deployment Flexibility**: The modules should enable deployment in various sites, ensuring widespread applicability.
Instrument /platform description
The Plankton dynamics Sensor Package (PSP), built around the so-called Costof2 (COmmunication and STOrage Front-end - 2nd generation) system developed by Ifremer, which is common to the EMSO Generic Instrument Module, represents a significant advancement in coastal multi-compartment observation. The system was designed to enhance coastal variable observation in an interoperable manner (Delory et al. 2021), based on a technological solution called the coastal EGIM (cEGIM). The coastal EGIM, meant to be transposable to other JERICO-RI sites, provides a platform aimed to address various scientific and societal needs. The module's drivers cover physics, chemistry, and biology, with the flexibility to develop new drivers. Notably, it incorporates biologically related sensors (zooplankton and nitrate) and an adaptive sampling strategy based on real-time observations. Among the innovations and benefits the cEGIM presents, we can highlight: **High TRL and Reliability:** The core electronic unit ensures robust interfacing between sensors and communication systems. **Versatility:** It can operate underwater (benthic or water column) and at the sea surface (buoys), or on jetties, autonomously or linked to other energy sources, and supports different communication means. **Sensor Library:** Access to existing sensor drivers inherited from coastal and open ocean observation initiatives and developments. **Openness:** Possibility to integrate new sensors and functions benefiting the entire user community. **Adaptive Sampling:** Innovative data science algorithms allow dynamic adjustments based on observations. **Interoperability:** Converges technically with the EMSO Generic Instrument Module, in particular for real-time standard data flow.

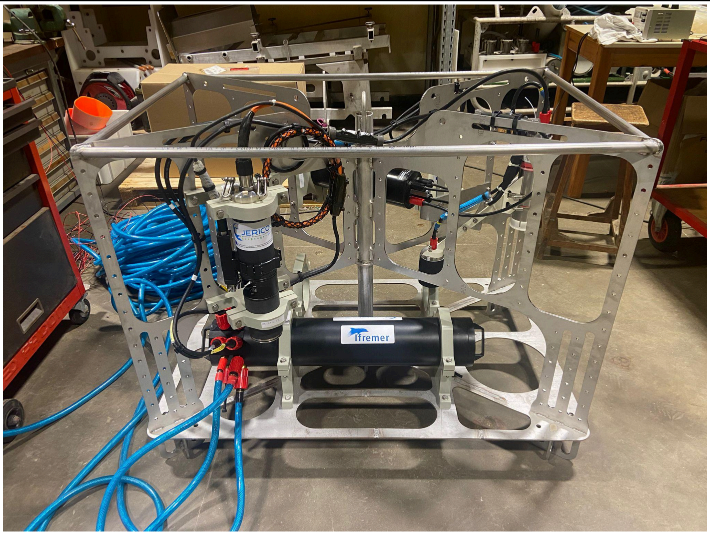

***Figure 1**: cEGIM under preparation before deployment*

In summary, the cEGIM responds to the PSP technological requirements, significantly enhances coastal monitoring capacity in Jerico, enabling efficient detection of phenomena like algal blooms and automation while providing standardized real-time data flow.

Innovations developed in Jerico-S3

- New driver developments and porting to COSTOF2 for biogeochemistry and biology
- Bloom detection algorithm development and porting to COSTOF2
- Cost reduction for coastal deployment down to 200m

Map of observation effort / Place of demonstration

The English Channel is a coastal continuum influenced by both the Atlantic Ocean and the North Sea. Its physical features, including bathymetry and coastline, give rise to specific hydrological structures such as fronts and gyres. These structures control the movement and dispersion of water, affecting the transport of nutrients, pollutants, and plankton across boundaries. One of the most notable hydrodynamic features in the English Channel is the tidal current intensity. Additionally, the region experiences significant impacts from swells and waves originating from the Atlantic or generated locally by wind events.

The English Channel's hydrological and biogeochemical conditions create favorable conditions for seasonal primary production. However, this intense productivity can also lead to eutrophication issues and harmful algal blooms. The system receives freshwater input from rivers, along with nutrients and particulate matter.

Human activities play a significant role in this region. It serves as an economic zone where various activities occur, including tourism, leisure, international ports, freight transportation, fisheries, aquaculture, and the extraction of non-living resources like marine aggregates

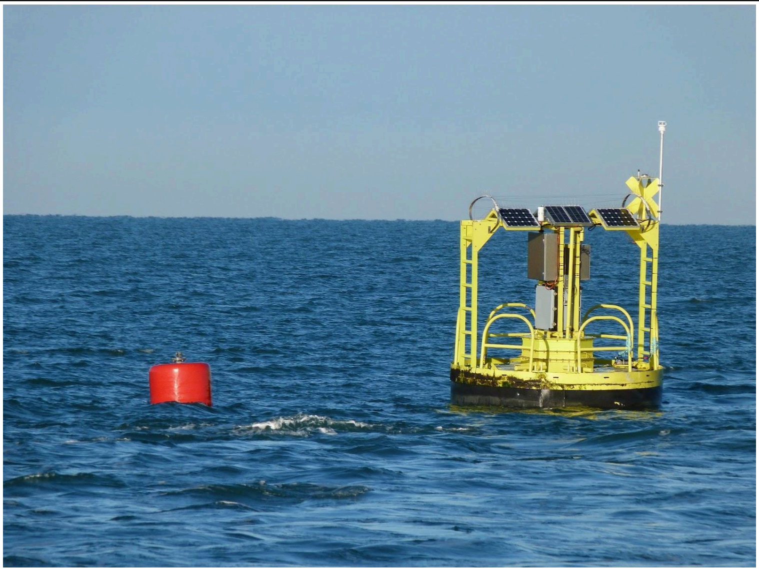

***Figure 2**: SMILE buoy at demonstration site in the English Channel*

The MAREL SMILE system, developed collaboratively by Ifremer (French Research Institute for Exploitation of the Sea) and the University of Caen Normandy in 2015, is a moored buoy strategically positioned 2 nautical miles north of Luc-sur-mer in the Central English Channel. This coastal observing network component operates autonomously, continuously collecting data related to the marine environment.

Mission report summary

The Coastal EGIM (cEGIM) was deployed by Ifremer on the **SMILE site** in the **JERICO-S3 English Channel Pilot Supersite**, off Luc sur Mer and the estuary of the Seine river, from **21 April to 15 June 2023**. During this deployment, cEGIM measured physical, chemical, and biological data at high resolution in standalone mode. The system also collected data for the embedded algal bloom detector algorithm. This demonstration was led by Ifremer (France) and coordinated in Jerico-S3 WP7 by PLOCAN (Spain) and CNR (Italy). Scientists from IFREMER, CNRS, and Université de Caen supported the demonstration.

***Figure 3**: cEGIM recovery from demonstration site*

Before this deployment, during the winter of **2022-2023**, cEGIM underwent pre-testing for functional validation. It was deployed at **8 meters water depth** in the **Sainte Anne du Portzic Bay**, near IFREMER in Brest, France. This pre-demo test was crucial for the success of the subsequent demonstration phase. The cEGIM configuration during the demonstration aimed to monitor plankton dynamics, addressing a key scientific challenge identified by the JERICO-RI community. Selection of sensors was based on a compromise between importance of variables, feasibility of developing a suitable driver for COSTOF2, and hardware availability. The selected sensors included: ● **BBE_Fluoroprobe** (for fluorescence measurement) ● **NKE_MP6** (a multiparameter probe measuring pressure, temperature, and salinity) ● **ISUS_Satlantic** (for nitrate measurement) All these sensors were controlled by the COSTOF2 electronic control unit. The AI-driven functionality, jointly developed by Université du Littoral de la Côte d'Opale and Ifremer, detects phytoplankton blooms using periodic measurements of fluorescence and nitrate content. The challenge consisted in integrating this algorithm with the COSTOF2 for in situ bloom detection and adjusting the sampling frequency of sensors during bloom periods to optimise measurement quality while saving energy. The cEGIM system, following extensive testing and in situ deployments in 2023, has demonstrated robustness and reliability. This high-resolution automated measurement system, equipped with on-board intelligence, enables an adaptive sampling strategy based on monitoring specific parameters. By adjusting its sampling frequency according to threshold values, the system achieves energy savings, allowing for longer deployments. The cEGIM monitored a phytoplankton bloom by tracking nitrate concentration and phytoplankton biomass (fluorescence), the system provided valuable insights into bloom phenology, including the relative frequency of different spectral groups of phytoplankton in response to environmental changes. Consideration of adding new sensors for multivariate observation further enhances our understanding of both low- and high-resolution processes related to phytoplankton blooms, including Harmful Algal Blooms (HAB). *Detailed information has been reported in Jerico-S3 Deliverable D7.7. This information is confidential at the time of writing this report because its content is being used in the writing of a journal paper. You can contact the development lead below for more information.*
Contributors: Jérome Blandin (Ifremer) - lead, Alain Lefevre (Ifremer), Felipe Artigas (CNRS), Laurent Coppola (CNRS), Joaquín del Rio (UPC), Enoc Martinez, (UPC), Simon Jorka (52North), Jérome Blandin (Ifremer), Emilie Poisson Caillault (Univ- Littoral), Michel Repecaud (Ifremer), Tanguy Bescond (Ifremer), Bertrand Moreau (Ifremer), Laurent Delauney (Ifremer), Andres Cianca (PLOCAN), Simone Marini (CNR), Eric Delory (PLOCAN)

CONCLUSION

The JERICO-S3 project's technological innovations demonstrated in the above activities, namely ACOBS, WASP, and PSP, represent notable advancements in coastal and marine observation capabilities. Each system addresses specific gaps in our current ability to observe and understand complex marine processes.

ACOBS has demonstrated its ability to conduct simultaneous measurements of various environmental variables, offering insights into benthic processes and sediment-water interactions. Further deployments, e.g. other environments are needed to fully optimize its capabilities, but clearly the technology can shed light on these important and insufficiently considered ecosystem processes and services.

WASP has shown potential for automated, high-precision sampling of seawater for nutrient and eDNA analysis. Its integration with existing FerryBox systems enhances our ability to monitor water quality and phytoplankton communities over large spatial and temporal scales. While promising, more extensive testing across diverse environments would be beneficial to validate its reliability and consistency.

The PSP, with its AI-driven adaptive sampling strategy, presents a new approach to monitoring phytoplankton dynamics. Its ability to adjust sampling based on real-time data is valuable for understanding phytoplankton blooms, including harmful algal blooms. Longer-term deployments and comparisons with traditional methods are necessary to fully assess its effectiveness.

These innovations contribute to a more comprehensive approach to marine ecosystem monitoring. By combining physical, chemical, and biological observations, they provide a broader view of marine ecosystems. However, it's important to note that these systems are still in developmental stages and require further refinement and validation.

The successful demonstrations of these technologies highlight both their potential and the need for continued development. Future efforts should focus on, *inter alia*:

1. Expanding deployments to diverse environments to test system robustness and adaptability.
2. Enhancing integration with existing observation networks to maximize data utility.
3. Addressing challenges such as biofouling and long-term stability to improve reliability during extended deployments.
4. Assessing their potential for industrial production

While these technological advancements show promise for improving our understanding and management of marine resources, it's crucial to approach their implementation with careful consideration of both their capabilities and limitations. Continued collaboration between researchers, engineers, end-users, operators and industry will be essential to refine these systems and realize their full potential in supporting marine science and policy.

REFERENCES

Eric Delory, Simone Marini, Jérôme Blandin, Catherine Boccadoro, Dominique Durand, et al. JERICO-S3 INTEGRATED INNOVATIVE TECHNOLOGIES FOR COASTAL MONITORING. 9th EuroGOOS International conference, Shom; Ifremer; EuroGOOS AISBL, May 2021, Brest, France. pp.186-192. ⟨hal-03334236v2⟩